

**METHOD AND APPARATUS FOR MICROWAVE INTERCONNECTION**

**BACKGROUND OF THE INVENTION**

1    1. Technical Field

2           The present invention pertains to interconnections for microwave signals. In  
3 particular, the present invention pertains to coupling microwave signals from a removable  
4 microwave module installed on a chassis plate to a microstrip transmission line installed in  
5 the chassis plate.

6  
7    2. Discussion of Related Technology

8           Microwave signals are typically processed and/or generated in microwave modules  
9 and coupled to microstrip transmission lines for signal transference and/or transmission.  
10 The microwave modules may be installed on a chassis plate, where the modules and  
11 chassis plate each contain a microstrip line. A conventional horizontal feedthrough  
12 approach of coupling microwave signals between the microwave module and a microstrip  
13 line on a chassis plate is illustrated in Fig. 1. Specifically, a microwave module 12 is  
14 installed on a chassis plate 10. The chassis plate includes a microstrip line 16, a microstrip  
15 channel 18 and a channel cover 20. Microwave module 12 is installed in a recessed  
16 section 22 of the chassis plate, while channel 18 is defined in a chassis plate raised portion  
17 adjacent the recessed section and houses microstrip line 16. Channel cover 20 is installed  
18 on the upper edges of channel 18 to cover the channel and enclose microstrip line 16  
19 therein. Microstrip line 16 is typically laid into channel 18, where the channel is machined  
20 into chassis plate 10 to allow the channel to be covered and thereby electrically isolated  
21 from other microstrip transmission lines.

22           Microwave module 12 processes and/or generates microwave signals, where a  
23 feedthrough pin 14 is installed through the side wall of the microwave module adjacent  
24 channel 18. Feedthrough pin 14 extends into microstrip channel 18 and is substantially  
25 parallel to microstrip line 16. The feedthrough pin is attached, either directly or indirectly,  
26 to microstrip transmission line 16 mounted on the chassis plate within channel 18. The  
27 feedthrough pin serves to couple microwave signals processed and/or generated by  
28 microwave module 12 to microstrip line 16.

1           The configuration described above has several disadvantages. In particular, the  
2 conventional horizontal feedthrough approach described above provides a gap between the  
3 microwave module side wall and the covered channel containing the microstrip line. This  
4 gap produces signal leakage that can impact isolation of other signals on the chassis plate.  
5 Although gaskets may be utilized to impede signal leakage, this is problematic due to the  
6 need to establish horizontal pressure on the gasket in a vertical mounting direction and to  
7 maintain adequate pressure on the gasket over temperature variations in the presence of  
8 possibly differing coefficients of thermal expansion (CTE) (e.g., the fractional increase in  
9 length of an object for each degree of increased temperature) between the microwave  
10 module and chassis plate. Further, the gasket is required to maintain equal pressure on the  
11 vertical faces of both the chassis plate raised portion and the channel cover, thereby  
12 requiring the channel cover to be installed with high precision to align exactly with the  
13 edge of the chassis plate raised portion. Some mechanical configurations are commonly  
14 utilized to rectify this problem; however, these tend to complicate the feedthrough  
15 approach.

16           In addition, the gap creates an inductive ground discontinuity by forcing return  
17 currents to flow down the chassis plate raised portion face and up the face of the  
18 microwave module wall. The greater the height of the microwave module, the more  
19 severe the discontinuity. Although ground ribbons may be installed on either side of the  
20 feedthrough pin or conductive material may be placed to fill the gap in order to mitigate  
21 the ground discontinuity, these courses of action require complicated assembly and are not  
22 electrically ideal.

## 23 24           **OBJECTS AND SUMMARY OF THE INVENTION**

25           Accordingly, it is an object of the present invention to feed microwave signals  
26 vertically through the bottom of a microwave module to a microstrip line on a chassis  
27 plate.

28           It is another object of the present invention to employ an electrically conductive  
29 gasket about a feedthrough pin extending between a microwave module and chassis plate  
30 to reduce signal leakage and enhance ground continuity, thereby enhancing feedthrough  
31 performance.

32           Yet another object of the present invention is to employ an insulating sleeve on a  
33 feedthrough pin extending between a microwave module and a chassis plate to permit a

1 larger chassis plate feedthrough passage to maintain system impedance (e.g., 50 ohms), to  
2 reduce sensitivity to mechanical misalignment and to prevent shorting of the feedthrough  
3 pin to the chassis plate due to assembly tolerances.

4 Still another object of the present invention is to provide a nominal clearance (e.g.,  
5 0.005 inches) between an insulating sleeve of a microwave module feedthrough pin and a  
6 microstrip channel in a chassis plate to render feedthrough impedance substantially  
7 insensitive to the position of the pin and sleeve within the channel and to accommodate  
8 manufacturing and assembly tolerances for single or plural pins in the microwave module.

9 The aforesaid objects may be achieved individually and/or in combination, and it is  
10 not intended that the present invention be construed as requiring two or more of the  
11 objects to be combined unless expressly required by the claims attached hereto.

12 According to the present invention, microwave signals are coupled from a  
13 removable microwave module disposed or installed on a chassis plate to a microstrip  
14 transmission line disposed or installed in the plate. The microwave signals are fed through  
15 the bottom or side of the microwave module using a feedthrough pin mounted in the  
16 module and hermetically sealed, if necessary. The feedthrough pin extends from the  
17 microwave module interior into a channel defined in the chassis plate and to a microstrip  
18 line on the opposite side of the plate. An electrically conductive gasket is disposed or  
19 installed about the feedthrough pin between the microwave module and chassis plate to  
20 reduce signal leakage and enhance ground continuity, thereby enhancing the voltage  
21 standing wave ratio (VSWR) performance of the feedthrough. The microwave module is  
22 installed in the same direction as the feedthrough pins, thereby allowing the use of  
23 fasteners to apply uniform, reliable pressure to the gasket and ensuring prevention of  
24 signal leakage. The electrically conductive gasket provides reliable, positive contact all  
25 around the feedthrough pin to prevent the ground discontinuity inherent within the  
26 conventional horizontal feedthrough approach as described above.

27 An insulating sleeve is disposed or installed about the feedthrough pin in the  
28 chassis plate channel. The sleeve prevents shorting of the pin to the chassis plate resulting  
29 from assembly tolerances and allows a larger feedthrough channel in the chassis plate to  
30 maintain system impedance (e.g., 50 ohms). The sleeve further reduces sensitivity to  
31 mechanical misalignment. The feedthrough pin and sleeve provide a nominal clearance  
32 (e.g., 0.005 inches) within the chassis plate channel. This allows for manufacturing and  
33 assembly tolerances for single or plural pins in the microwave module and enables

1 feedthrough impedance to be substantially insensitive to the radial position of the  
2 feedthrough pin and insulating sleeve within the channel.

3 The above and still further objects, features and advantages of the present  
4 invention will become apparent upon consideration of the following detailed description of  
5 specific embodiments thereof, particularly when taken in conjunction with the  
6 accompanying drawings wherein like reference numerals in the various figures are utilized  
7 to designate like components.

### 8 9 **BRIEF DESCRIPTION OF THE DRAWINGS**

10 Fig. 1 is a view in elevation and partial section of a conventional horizontal  
11 feedthrough configuration for coupling microwave signals between a microwave module  
12 and a microstrip line on a chassis plate.

13 Fig. 2 is a view in elevation and partial section of a feedthrough configuration for  
14 coupling microwave signals between a microwave module and a microstrip line on a  
15 chassis plate according to the present invention.

16 Fig. 3 is a bottom view in partial section of the insulating sleeve and feedthrough  
17 pin of Fig. 2 installed in a substantially concentric fashion within the chassis plate channel.

18 Fig. 4 is a bottom view in partial section of the insulating sleeve and feedthrough  
19 pin of Fig. 2 installed within the chassis plate radially offset from a substantially  
20 concentric position.

21 Fig. 5 is a plot graphically illustrating the relationship between impedance and the  
22 insulating sleeve and feedthrough pin radial position within the chassis plate channel.

23 Fig. 6 is a bottom view in plan of the chassis plate, insulating sleeve and  
24 feedthrough pin of Fig. 2 including the microstrip line with capacitive stubs to compensate  
25 for inductance of the wire interconnect between the microstrip line and feedthrough pin  
26 according to the present invention.

27 Fig. 7 is a view in elevation and partial section of an alternative feedthrough  
28 configuration for coupling microwave signals between a microwave module and a  
29 microstrip line on a chassis plate according to the present invention.

### 30 31 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

32 A configuration for coupling microwave signals between a microwave module and  
33 a microstrip transmission line disposed or installed on a chassis plate according to the

1 present invention is illustrated in Figs. 2 - 4. Specifically, the configuration includes a  
2 microwave module 100, a chassis plate 102 and a feedthrough pin 104 coupling  
3 microwave signals between the microwave module and chassis plate as described below.  
4 Microwave module 100 includes corresponding electronics (not shown) to generate and/or  
5 process microwave signals for transference to the chassis plate and may be implemented  
6 by any conventional or other devices. The microwave module is disposed or installed  
7 adjacent and above chassis plate 102 to provide a vertical arrangement and includes a  
8 microstrip transmission line 108 disposed or installed therein that receives microwave  
9 signals from the module electronics. Microstrip line 108 may be installed within an  
10 enclosed channel 150 defined in the microwave module and is oriented substantially  
11 perpendicular to feedthrough pin 104 to provide microwave signals to the feedthrough pin  
12 via a wire or ribbon bond 132. By way of example only, the configuration of Fig. 2  
13 illustrates a right-angle launch (e.g., with respect to the positions of the microstrip line and  
14 feedthrough pin) inside the microwave module, but the present invention may be applied  
15 to other types of launches as described below. It is to be understood that the terms “top”,  
16 “bottom”, “front”, “rear”, “side”, “height”, “width”, “length”, “upper”, “lower”, “right”,  
17 “left”, “vertical”, “horizontal” and the like are used herein merely to describe points of  
18 reference and do not limit the present invention to any particular configuration or  
19 orientation.

20 The feedthrough pin is substantially cylindrical and is disposed or installed in a  
21 substantially cylindrical passage 130 defined within the microwave module and extending  
22 from microstrip line 108 toward a microwave module bottom wall 134. The dimensions  
23 of passage 130 are chosen to achieve the desired system impedance (e.g., 50 ohms) when  
24 coupled with feedthrough pin 104. Feedthrough pin 104 extends within passage 130 from  
25 the microwave module interior and through microwave module bottom wall 134 into  
26 chassis plate 102. A seal 106, preferably a conventional hermetic glass-to-metal seal, is  
27 disposed or installed about feedthrough pin 104 within the microwave module toward the  
28 module bottom wall to maintain hermicity within the microwave module. The microwave  
29 module includes a recessed section 136 defined in the module bottom wall and extending  
30 to a distal end of passage 130. The recessed section includes dimensions sufficient to  
31 accommodate the seal. Seal 106 may be installed within microwave module 100 via any  
32 conventional installation materials 110 (e.g., adhesives, solder, etc.) or other techniques.  
33 For example, feedthrough pin 104 may be a prefabricated feedthrough pin with a glass-

1 to-metal seal for soldering within the microwave module, or the feedthrough pin and seal  
2 may be fired directly into place in the microwave module.

3 The microwave module bottom wall is fastened to a chassis plate top wall 138,  
4 while an electrically conductive gasket 112 is disposed or installed between the underside  
5 of seal 106 and the chassis plate top wall. The gasket is substantially annular in the form  
6 of a circular ring and includes dimensions slightly greater than those of seal 106.  
7 Feedthrough pin 104 is concentrically disposed or installed through the gasket for the  
8 purpose of creating a continuous electrical shield around the feedthrough pin when that pin  
9 traverses a gap between the microwave module bottom wall and the chassis plate. The  
10 gasket reduces signal leakage and enhances ground continuity, thereby enhancing the  
11 voltage standing wave ratio (VSWR) performance of the feedthrough. The microwave  
12 module is installed in the same direction as the feedthrough pin, thereby allowing the use  
13 of fasteners to apply uniform, reliable pressure to the gasket and ensuring prevention of  
14 signal leakage. This enables the gasket to provide reliable, positive contact all around the  
15 feedthrough pin to prevent ground discontinuity. The gasket is preferably constructed of a  
16 deformable metal (e.g., gold, copper, tin, lead, indium, any alloys thereof, or other suitable  
17 materials) and includes a diameter selected to minimize the discontinuity between the seal  
18 and the chassis plate.

19 A substantially cylindrical channel 114 is defined in the chassis plate generally  
20 coincident with passage 130 of the microwave module. Plate channel 114 receives the  
21 portion of feedthrough pin 104 extending external of the microwave module, and extends  
22 from the chassis plate top wall to a microstrip transmission line 120 disposed or installed  
23 within the chassis plate. An insulating sleeve 116 is disposed or installed about  
24 feedthrough pin 104 within plate channel 114 to form a controlled-impedance coaxial  
25 signal path vertically through the chassis plate. The insulating sleeve is designed to have  
26 an interference fit to the feedthrough pin, thereby eliminating the need for mechanical  
27 capture to secure the sleeve to the pin. The insulating sleeve is preferably fabricated from  
28 a relatively pliable material, such as PTFE, to allow the sleeve to be easily pressed on the  
29 feedthrough pin. Feedthrough pin 104 extends beyond the distal ends of the sleeve and  
30 plate channel and is coupled to plate microstrip line 120 via a wire or ribbon bond 118.  
31 The plate microstrip line is placed perpendicular to the portion of feedthrough pin 104  
32 extending beyond the plate channel and receives microwave signals from the feedthrough  
33 pin via wire bond 118. The plate microstrip line may be installed within an enclosed

1 channel 142 defined in the chassis plate and basically provides microwave signals for  
2 various applications.

3 The respective dimensions of the feedthrough pin, insulating sleeve and plate  
4 channel are designed to achieve a coaxial transmission medium impedance matched to the  
5 required system impedance, typically 50 ohms. Plate channel 114 includes dimensions  
6 sufficient to form a clearance gap 122, preferably on the order of 0.005 inches on the  
7 radius, between insulating sleeve 116 and the plate channel wall to allow for fabrication  
8 and assembly tolerances for single or plural pins in the microwave module. The position  
9 of the feedthrough pin and insulating sleeve within plate channel 114 may deviate from a  
10 concentric or coaxial location (Fig. 3). The maximum distance this position may deviate  
11 is limited by the clearance gap (Fig. 4). The insulating sleeve serves to reduce impedance  
12 variations caused by deviation of the feedthrough pin from the coaxial position within the  
13 plate channel. The insulating sleeve further serves to prevent shorting of the pin to the  
14 plate channel wall resulting from assembly tolerances and allows a larger diameter  
15 channel in the chassis plate to maintain system impedance (e.g., 50 ohms).

16 By way of example only, the feedthrough pin may include a diameter of  
17 approximately 0.020 inches, the insulating sleeve may include an outer diameter of  
18 approximately 0.051 inches, and the plate channel may include an inner diameter  
19 approximately 0.061 inches, while the insulating sleeve may be constructed of PTFE.  
20 With these dimensions and materials, the characteristic impedance of the coaxial  
21 transmission configuration varies only 2.8%, from 50.0 ohms to 48.6 ohms (a VSWR of  
22 1.03:1), as the position of the feedthrough pin varies from the coaxial position to a  
23 maximum deviated position offset from the coaxial position by the clearance gap (e.g.,  
24 0.005 inches). A graphical illustration of this relationship, by way of example only, is  
25 illustrated in Fig. 5. Without the insulation sleeve, a comparable 50 ohm configuration  
26 with a feedthrough pin diameter of 0.020 inches requires a channel inner diameter of 0.046  
27 inches. In this case, a feedthrough pin position offset of 0.005 inches causes an impedance  
28 variation of 7.4%.

29 Referring to Fig. 6, printed capacitive stubs 124, preferably two, are connected to  
30 microstrip line 120 proximate wire or ribbon interconnect 118 installed between the  
31 microstrip line and the feedthrough pin within the chassis plate. The stubs are preferably  
32 in the form of butterfly stubs, with each stub extending transversely from an opposing  
33 microstrip line longitudinal side. The stubs are employed to compensate for the

1 inductance of the wire or ribbon interconnect and to reduce the electrical reflection at high  
2 frequencies. The stubs may alternatively be implemented by any suitable devices or  
3 techniques to obtain a shunt capacitance in close proximity to the interconnect wire or  
4 ribbon. In addition, the capacitive stubs may be employed for the interconnection between  
5 microstrip line 108 (Fig. 2) of the microwave module and the feedthrough pin in  
6 substantially the same manner described above.

7 The present invention may alternatively be employed with various types of  
8 launches. By way of example only, a horizontal launch (e.g., with respect to the positions  
9 of the microwave module microstrip line and feedthrough pin) is illustrated in Fig. 7.  
10 Initially, this configuration is substantially similar to the configuration described above for  
11 Fig. 2, except that microstrip line 108 is placed within the microwave module substantially  
12 parallel to feedthrough pin 104. Specifically, the configuration includes microwave  
13 module 100, chassis plate 102 and feedthrough pin 104 with seal 106 and sleeve 116, each  
14 substantially similar to the corresponding components described above. The feedthrough  
15 pin couples microwave signals between the microwave module and chassis plate as  
16 described above. The microwave module is installed adjacent and above chassis plate 102  
17 to provide a vertical arrangement and includes microstrip transmission line 108 placed  
18 therein that receives microwave signals from microwave module electronics as described  
19 above. The microstrip line may be installed within an enclosed channel 152 defined in the  
20 microwave module, and is positioned slightly offset from and substantially parallel to  
21 feedthrough pin 104 for connection to that pin via direct solder 170 or a ribbon 180 to  
22 provide microwave signals to the feedthrough pin.

23 The feedthrough pin is placed in passage 130 defined within the microwave  
24 module and extending from microstrip line 108 toward microwave module bottom wall  
25 134 as described above. The lengths of passage 130 and the feedthrough pin portion  
26 placed within the microwave module are less than the lengths of the corresponding  
27 components described above for Fig. 2 due to the vertical orientation of the module  
28 microstrip line. Feedthrough pin 104 extends within passage 130 from the microwave  
29 module interior and through microwave module bottom wall 134 into chassis plate 102.  
30 Seal 106 is installed about feedthrough pin 104 within the microwave module toward the  
31 module bottom wall as described above.

32 The microwave module bottom wall is fastened to a chassis plate top wall 138,  
33 while gasket 112 is installed about the feedthrough pin between the underside of seal 106



1 and the chassis plate top wall as described above. Channel 114 is defined in the chassis  
2 plate generally coincident passage 130 of the microwave module and receives the portion  
3 of feedthrough pin 104 extending external of the microwave module as described above.  
4 Insulating sleeve 116 is placed about feedthrough pin 104 within plate channel 114, where  
5 the feedthrough pin extends beyond the distal ends of the sleeve and plate channel and is  
6 coupled to plate microstrip line 120 via wire or ribbon bond 118 as described above. The  
7 respective dimensions of the feedthrough pin, insulating sleeve and plate channel form  
8 clearance gap 122 within the plate channel between the insulating sleeve and plate channel  
9 wall as described above. The plate microstrip line is installed substantially perpendicular  
10 to the portion of feedthrough pin 104 extending beyond the plate channel and receives  
11 microwave signals from the feedthrough pin via wire bond 118. The plate microstrip line  
12 may be positioned within an enclosed channel 142 defined in the chassis plate and  
13 provides microwave signals for various applications as described above.

14         The present invention provides interconnection of microwave modules to a chassis  
15 plate with significant reduction in signal leakage relative to the conventional horizontal  
16 feedthrough, while retaining at least comparable tolerance to assembly and manufacturing  
17 variations.

18         It will be appreciated that the embodiments described above and illustrated in the  
19 drawings represent only a few of the many ways of implementing a method and apparatus  
20 for microwave interconnection.

21         The microwave module may be of any quantity, type, shape or size and may be  
22 placed at any suitable locations on the chassis plate. The microwave module may include  
23 any suitable configuration with any quantity of passages, channels, cavities or chambers of  
24 any shape or size placed or defined in the module at any locations in any orientations. The  
25 module passages and recessed section may be of any quantity, shape or size and may be  
26 disposed or defined in the module at any locations in any orientations. The microwave  
27 module may be secured or attached to the chassis plate via any conventional or other  
28 techniques (e.g., removably attached, fastened, secured, etc.). The microwave module  
29 may include or be coupled to any conventional or other circuitry, electronics or devices to  
30 generate and/or process signals at any desired frequency (e.g., microwave, etc.). These  
31 components may be installed at any locations and may be coupled or provide the resulting  
32 signals to the module or microstrip line in any fashion (e.g., directly connected, a

1 conductor, etc.). The present invention may be utilized with launches in any desired  
2 orientations.

3 The chassis plate may be of any quantity, shape or size and may be constructed of  
4 any suitable materials. The chassis plate may include any suitable configuration with any  
5 quantity of channels, cavities or chambers of any shape or size installed or defined in the  
6 plate at any locations in any orientations. The plate channels may be of any quantity,  
7 shape or size and may be positioned or defined in the chassis plate at any locations in any  
8 orientations. The present invention may be employed to transfer signals between any  
9 quantity of microwave modules and any quantity of any type of mounting structure (e.g.,  
10 chassis or other plate, platform, brackets, etc.) for any applications.

11 The feedthrough pin may be of any quantity, shape or size, may be installed at any  
12 locations in any orientations and may be constructed of any materials suitable for  
13 conducting signals. The feedthrough pin may be implemented by any type of  
14 conventional or other conductors. The feedthrough pin may be installed or attached to the  
15 microwave module and chassis plate via any conventional or other fastening techniques.  
16 The feedthrough pin and corresponding components (e.g., sleeve, seal, etc.) may be  
17 separate components or be attached or formed integral with each other in any desired  
18 combinations. The pin may be solid or include any degree of hollowness sufficient to  
19 transfer signals. The feedthrough pin may be installed in or through any walls of the  
20 microwave module and chassis plate (e.g., top, bottom, side, etc.).

21 The seal may be of any quantity, shape or size, may be installed at any locations in  
22 any orientations and may be implemented by any conventional (e.g., glass-to-metal  
23 hermetic seal, etc.) or other seals. The seal is preferably a hermetic seal, but may be  
24 utilized without being hermetically sealed. The seal may be installed or attached to the  
25 microwave module via any conventional or other fastening techniques and/or materials  
26 (e.g., adhesives, solder, etc.).

27 The gasket may be of any quantity, shape or size, may be installed at any locations  
28 in any orientations and may be constructed of any suitable materials (e.g., gold, copper,  
29 tin, lead, indium, any alloys thereof, etc.). The gasket may be installed or attached to the  
30 microwave module and chassis plate via any conventional or other fastening techniques or  
31 materials (e.g., fasteners, adhesives, grooves, etc.). The gasket may be implemented by  
32 any type of conventional or other spacer having suitable conductive properties.

1           The insulating sleeve may be of any quantity, shape or size, may be installed at any  
2 locations in any orientations and may be constructed of any suitable materials (e.g., PTFE,  
3 etc.). The insulating sleeve may be attached to the feedthrough pin via any conventional  
4 or other fastening techniques and may partially or entirely surround any portions of the  
5 feedthrough pin. The clearance formed between the insulating sleeve and channel wall is  
6 preferably approximately 0.005 inches, but may be of any suitable dimensions.

7           The wire or ribbon bonds may be of any quantity, shape or size, may be positioned  
8 at any suitable locations and may be constructed of any suitable materials to transfer  
9 signals. The wire bonds may be implemented by any conventional or other conductors.  
10 The microstrip transmission lines may be of any quantity, shape or size, may be disposed  
11 at any suitable locations and may be constructed of any suitable materials to transfer  
12 signals. The microstrip lines may be implemented by any conventional or other  
13 conductors, may be secured to the microwave module and chassis plate via any  
14 conventional or other fastening techniques and may be installed at any orientations relative  
15 to the feedthrough pin. The microstrip lines may be coupled to the feedthrough pin via  
16 any conventional or other techniques (e.g., direct contact, via any conductors, etc.). The  
17 stubs may be of any quantity, shape or size, may be positioned at any suitable locations  
18 and may be constructed of any suitable materials. The stubs may be implemented by any  
19 conventional or other devices or techniques to obtain a shunt capacitance.

20           From the foregoing description, it will be appreciated that the invention makes  
21 available a novel method and apparatus for microwave interconnection, wherein  
22 microwave signals are coupled from a microwave module to a chassis plate microstrip line  
23 via a feedthrough pin including an insulating sleeve and a conductive gasket installed  
24 between the module and plate to reduce signal leakage and enhance feedthrough  
25 performance.

26           Having described preferred embodiments of a new and improved method and  
27 apparatus for microwave interconnection, it is believed that other modifications, variations  
28 and changes will be suggested to those skilled in the art in view of the teachings set forth  
29 herein. It is therefore to be understood that all such variations, modifications and changes  
30 are believed to fall within the scope of the present invention as defined by the appended  
31 claims.